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U.S. DEPARTMENT OF ENERGY
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SUMMARY

Results of the recently completed Engineering Test Facility (ETF) studies are reviewed. These three parallel independent studies were conducted by industrial teams led by the AVCO Everett Research Laboratory, the General Electric Corporation, and the Westinghouse Corporation. A preliminary analysis and the status of the critical evaluation of these results are presented.

INTRODUCTION

Power plant studies have shown the attractiveness of MHD topped steam power plants for baseload utility applications. To realize these advantages, DOE has embarked a three-phase development program. In the first phase, the engineering data and experience will be developed for the design and construction of a pilot plant, the Engineering Test Facility (ETF). In the second phase, ETF will be designed, built, and operated. ETF is envisioned as a fully integrated MHD/steam system, operating at the minimum scale necessary to demonstrate and verify the MHD concept and still be of interest to utilities. The third phase of the MHD program will demonstrate baseload power plant performance at several hundred electrical megawatts from a commercial demonstration plant. A possible accelerated option plan would commercialize MHD earlier, through utility participation in ETF.

Thus, ETF is envisioned as providing the major DOE focus in implementing the commercialization of MHD. As indicated in figure 1, the ETF is the goal towards which the major ongoing technology component development programs are directed and which, in turn, must lead to an attractive near-term prospect for a commercial power plant.

*Work supported by the U.S. Department of Energy.

To insure that this occurs, requires a continuing effort in systems engineering and supporting technology.

The goals of ETF are: 1) to demonstrate the engineering feasibility of design, construction, and operation of a fully integrated MHD/steam power plant; 2) to demonstrate the technological readiness of the entire MHD concept, including availability, reliability, environmental acceptability, construction feasibility, and operational practicability over a range of loadings and emergency conditions; 3) to provide component, subsystem, and system design data appropriate for scale-up to commercial plant sizes, while at the same time meeting the required construction and operating cost goals; 4) to provide a facility for resolving critical problems and acquiring design data concerning component interactions, control characteristics, and performance capabilities; and 5) to provide economic data that will permit the evaluation of the cost of early commercial MHD power plants.

To initiate the definition of the ETF plant, the DOE competitively procured parallel conceptual design and systems engineering studies. The DOE supplied only general guidelines for these studies in order to encourage and not limit contractor ideas. The contractors were each directed to investigate three alternative plants, plant arrangements, or operating conditions and then to recommend to DOE a specific plant configuration for additional study. The three contractor teams selected, as shown in Table 1, were led by the AVCO Everett Research Laboratory, Inc., the General Electric Company, and the Westinghouse Electric Corporation. The scopes of the various contracts differed. The AVCO Everett Research Lab and the General Electric Company contracts were of similar level of effort, but the level of effort and corresponding level of detail of the Westinghouse contract was approximately one-third that of the other two contractors. DOE directed AVCO and G.E. to complete their recommended reference plant designs, but directed Westinghouse to concentrate its additional effort on an MHD test facility smaller but similar to the initial phase of their recommended expandable plant.

Midway through these ETF conceptual studies, the DOE requested that Argonne National Laboratory, Gilbert Associates, Inc., and Lewis Research Center form an ETF project coordinating committee with Lewis acting as lead. The function of this committee was to advise the DOE in managing the contractual studies, to improve the comparability of the results, evaluate the results of the study contracts, and identify issues relevant to the further definition of the ETF. The ETF project coordinating committee members, the authors of this paper, in turn formed the 12 technical review teams indicated in Table 2, to assist them in this activity*.

*The authors would like to acknowledge the contributions of these technical review teams to the preparation of this paper.

This paper will briefly compare the results of the ETF conceptual studies conducted by AVCO, G.E., and Westinghouse. It will attempt to indicate both where there is agreement and where there are differences of opinions between the various contractors. As appropriate, results of independent analysis and/or viewpoints of the ongoing critical evaluation of these results by the review teams will also be indicated. The performance estimates of the final expanded plants recommended by the three contractors will be compared. However, cost and schedular comparisons will be limited to the AVCO and G.E. plants, which are much more similar to each other than to the Westinghouse plant. The recently completed contractor reports are references 1-3.

SUMMARY OF CONTRACTOR RECOMMENDED ETF PLANTS

The contractor recommended plants are summarized in Table 3. As a result of the general guidelines provided to the contractors, each of the studies had its own emphasis and each of the resulting plants had some unique aspects. The Westinghouse study focused more on the systems analysis of alternative plant configurations and sizes than on component design. Westinghouse restricted the study to plants having directly fired air preheaters. This choice was based on the high efficiency and low COE (cost of electricity) of large commercial plants of this type as demonstrated in studies such as ECAS (ref. 4). Westinghouse recommended an ETF which evolved from an initial MHD test train facility using oxygen-enriched air recuperatively preheated to 1520F to a MHD/steam plant using air directly preheated to 2500°F. The 340 MW_T fuel input to the plant was selected to mate the smallest available steam turbine generator. This is a relatively large plant; however, to mate a specific turbine, a plant using a directly-fired air preheater must have a higher thermal input than one using a separately-fired preheater. This results since a larger amount of waste heat is recycled in the directly preheated plant and, thus, is not available to the steam turbine.

AVCO and General Electric elected to study MHD plants having 2500-3000F separately-fired air preheaters and total plant fuel inputs of 250-300 MW_T. Their rationale was to eliminate the developmental risk of the directly-fired air heater, but it presupposes that a favorable efficiency and cost of electricity can be obtained with commercial-scale plants of this type. The Lewis Research Center has initiated with AVCO and G.E., under DOE funding, early commercial MHD power plant studies to assess these assumptions. The goal of these studies is to define MHD/steam plants which have performance greater than 45% and acceptable COE, but with lower development costs and risks than the directly preheated ECAS-type plants.

Net plant efficiency of the separately-fired ETF plants varied from 29% for the G.E. plant to 32% for the AVCO plant. The Westinghouse directly preheated plant had an efficiency that was approximately 34%.

The emphasis of the AVCO study was on examining one basic configuration at various conditions, including some aspects of off-design. The AVCO plant made special provisions for testing the MHD topping cycle, using an exhaust scrubber, prior to the integration of the topping cycle with the downstream heat and seed recovery system. An auxiliary boiler provided steam for the turbine drive of the air compressor for pretesting the MHD train. The design of the heat and seed recovery system assumed the applicability of Kraft recovery boiler technology. AVCO also examined the use of a coal gasifier to provide the fuel for the separately-fired air preheater.

The emphasis of the General Electric study was on the evaluation of alternative component designs for the plant; two types each of air heaters, combustors, channels, and inverters were designed and evaluated. The G.E. concept was to collect the seed as a liquid utilizing hot refractory lined cyclones. Seed reprocessing was, however, not within the scope of their contract. They utilized a motor-driven air compressor which permits them to have the largest steam bottoming turbine of all the contractors despite the fact that they have the lowest total steam bottoming cycle thermal input. They included provisions for independent combustor checkout and for stand-alone steam bottoming plant operation. For both of these provisions, the motor-driven air compressors offers an advantage.

As indicated in Table 3, there are substantial differences between the contractor recommended combustor types. AVCO selected a single-stage combustor with low heat loss and slag rejection of up to approximately 80%. The General Electric Company preferred design used a two-stage combustor with a novel fluid bed gasifier first stage which allows for 99+% ash rejection; it permits electrical isolation of the combustor between the combustor stages thus maintaining the entire coal feed and slag removal systems at ground potential. It also minimizes the slag that must be accommodated in the downstream heat and seed recovery system and allows the use of hot-walled channels. This novel fluidized bed is assumed to operate at a questionably low fuel to oxidizer ratio and utilizes a continuously recirculating sand bed to control its temperature. The sand carries from the combustor substantial amounts of unburned carbon and unrecoverable thermal power. Westinghouse selected a more conventional two-stage combustor concept with approximately 90% slag rejection.

All the contractors elected to operate the MHD generator at a high subsonic Mach number. All used magnetic fields of 6 tesla maximum.

AVCO and Westinghouse selected similar steam turbine bottoming plants with 950F steam and no reheat (1265 and 1300 psia, respectively). G.E. elected to generate 1000F supercritical steam (3500 psi) on the assumption that ultimately commercial plants would use supercritical steam bottoming cycles; therefore, the ETF should also generate supercritical steam. The G.E. design then throttles the steam to 2400 psi and 950F to mate an available small 1000F reheat steam turbine.

COMPARISON OF CONTRACTOR ETF PLANT PERFORMANCE

Figure 2 and Table 4 summarize the performance of the 3000F preheated AVCO plant, the 3000F preheated General Electric preferred plant, and the Westinghouse recommended plant (ETF-3). Figure 2 shows the power at various locations in these plants on a simplified MHD/steam cycle diagram. Table 4 is a summary of various nondimensional quantities for these plants.

In the AVCO and G.E. separately-fired preheater plants, approximately 34-35% of the fuel is used to fire the preheaters. The AVCO plant has a higher performance preheater design which allows for greater recycling of heat than does the G.E. preheater, 23 vs 13% of the total preheater power input. The AVCO design accomplishes this by recuperatively preheating to 1100F the combustion air for separately firing the air heater. Recycled stack gas to control the air-heater combustor temperature and limit NO_x production is also recuperatively preheated to 1100F. The General Electric air heater utilizes a pressurized combustor for reheat. It recycles only the heat of compression in a balanced turbine compressor plus the recycling of preheater exhaust. Because the G.E. fluid bed requires 1000F air, only the air to the second stage combustor is preheated to 3000F; if all the air had been preheated to 3000F, the G.E. plant configuration would have required a higher ratio of preheater fuel to total fuel than the AVCO plant. The directly-preheated Westinghouse plant, of course, obtains all the air preheat from the MHD exhaust by recuperation and regeneration.

The ratio of the power input to the MHD generator to that of the MHD combustor was calculated to be 94% for the AVCO single-stage combustor, 85% for the G.E. two-stage combustor employing the first-stage fluidized bed, and 91% for G.E.'s alternate two-stage cyclone combustor. Westinghouse assumed 95% for their two-stage combustor.

The ratio of the gross MHD power to the MHD generator thermal input (the MHD generator enthalpy extraction) ranged from 16% for AVCO and G.E. plants up to 18% for the higher-mass flow Westinghouse plant. The ratio of the net MHD power (i.e., MHD generator output minus compressor power) to the MHD generator input, however, varied from 12% for the AVCO and Westinghouse plants to 10% for the G.E. plant. The improved relative performance of the AVCO plant results from its low pressure drops in the regenerative air preheater and in the heat and seed recovery portions of the plant. In addition, the AVCO and Westinghouse plants have higher performance compressors for the MHD air than the multiple small motor-driven compressors used by G.E. The high pressure drop in the G.E. MHD combustion air stream results from the use of a small pressurized reheat air heater. The higher pressure drop in the heat and seed recovery system of the G.E. plant is due in part to the cyclone seed separators. The higher pressure drop of the Westinghouse plant heat and seed recovery system mainly results from the pressure

drop in the directly-fired high-temperature and low-temperature air preheaters.

The AVCO plant, as a result of its lower stack temperature, has a lower ratio of stack power than those of G.E. or Westinghouse. In the G.E. plant, the ratio of other power losses to the total fuel input is large because of the high heat losses in the fluid bed first-stage combustor.

The steam bottoming cycles devised by the contractors vary in efficiency from 33% for the AVCO plant to 37% for the high-performance G.E. cycle (2400 psia, 950F, 1000F). Independent analysis of these steam bottoming cycles by Gilbert Associates, Inc. predicts slightly higher performance than was calculated by AVCO and G.E., but calculates more than a point lower in efficiency than Westinghouse. The Westinghouse steam bottoming cycle is essentially identical to that used by AVCO and should have only slightly higher performance. Estimates in the bottoming cycle performance would not, however, cause more than a one point change in the total plant efficiency.

Both AVCO and G.E. estimate the efficiency of their inverter systems to be 98%. The two contractors, however, utilize substantially different inverter concepts. AVCO utilizes electrode consolidation techniques to limit the number of inverters required. G.E. assumes a Faraday channel with each electrode having its own DC to DC converter employing a high frequency chopper. The currents are then combined and fed into the final inverter system. The G.E. system, although somewhat more costly, allows for individual control of each electrode in the channel. Westinghouse conservatively estimated the efficiency of the inverter system to be 96%.

The contractors have substantial differences in their estimates of the ratio of the auxiliary power to the gross power of their EFT plants. AVCO estimates this quantity to be 10%; G.E., 13%; and Westinghouse, only 7%.

AVCO selected for seed reprocessing the relatively low energy consumption formate process. As a result, AVCO's ratio of seed reprocessing power to the total fuel input is small, 0.2%. The difficulty with the formate process is, however, that it produces a waste product similar to that of present generation limestone scrubbers which is not desirable for landfills. In fact, it has been speculated that ultimately such waste products may be determined to be environmentally unacceptable. Westinghouse elected to use the PERC seed reprocessing process. The energy cost associated with this process caused the Westinghouse's ratio of seed reprocessing power to total fuel input to be 2.2%. The difficulty with the proposed PERC process is the uncertainty of the process' chemical reaction rates. The Government seed reprocessing review team felt that no contractor had defined a method of seed reprocessing that could be definitely determined to be desirable. Alternative processes, not examined in

detail by the contractors, deserve additional study along with the processes selected by AVCO and Westinghouse.

The thermodynamic cycle efficiency of the separately-fired preheater ETF plant designs varied from 35% for the AVCO plant to 34% for the G.E. plant. The G.E. plant had higher heat losses associated with the combustor and higher plant pressure drops. These were essentially offset by the substantially higher efficiency of the G.E. bottoming cycle. The Westinghouse directly-fired preheater plant, as expected, obtained higher performance than the separately-fired plants, 38%.

Subtracting the inverter losses and auxiliary powers from the plants reduces their efficiencies by five points for the G.E. plant, three points for the AVCO plant, and two points for the Westinghouse plant. The resulting net efficiencies are 29% for G.E., 32% for AVCO, and 36% for Westinghouse. Including the seed reprocessing power does not affect the AVCO plant efficiency because of the low formate process losses. Use of the PERC process, even with low sulfur Montana coal, reduces the Westinghouse plant efficiency one point.

COMPARISON OF AVCO AND G.E. ETF COSTS

The AVCO and G.E. plants are both indirectly fired and are roughly the same size. Although they differ in numerous particulars, some comparison of their costs and the dominant cost drivers is instructive. The total AVCO costs, including engineering and contingency, are \$235MM whereas the G.E. costs were \$47MM larger (\$282 MM) for a slightly smaller plant. These totals are broken down in figure 3 into 10 standard major cost categories, which were specified to the contractors by the review committee. Slightly less than half of the costs of both plants are accounted for by the MHD topping cycle and, not surprisingly, the bulk of the difference in the costs of the two plants are in the topping cycle. The second largest difference in the costs of the two plants is in the turbine-generator cost code. The higher costs of the G.E. plant reflect the choice of a high-performance 2400 psi reheat turbine and a very high cost dry cooling tower which G.E. believes to be mandated by the lack of water at the specified Montana site.

Figure 4 focuses on the MHD topping cycle and shows that the good agreement between the cost totals may be deceptive. Significant disagreements are seen in most categories which can be attributed to differences in both designs and cost assumptions. Design differences are a major factor in the combustion equipment costs where the two-stage G.E. combustor is much more complex than the AVCO single-stage design. The differences in the magnet costs, which are even greater than they appear because the AVCO design has three times the working volume of the G.E. design, must be laid largely to differences in construction technique and costing methods.

Both contractors specify 3000F air preheaters, but develop quite different designs: AVCO uses conventional European hot-stove technology, upgraded to 3000F through the use of high purity alumina ceramics. G.E. also uses the expensive alumina, but reduces its volume by a factor of six through the use of pressurized combustion and other advanced technology. General Electric used A. G. McKee Inc., a hot stove manufacturer, to design a near-state-of-the-art 2700F heater using conventional ceramics. The fabrication cost is similar to that of the G.E. advanced design, but the development and contingency costs should be much lower.

The examples cited illustrate both the difficulty in obtaining reliable cost estimates for developmental components and also the importance of doing so. Design specifications, such as the air preheat temperature or the type of cooling tower, can significantly affect the overall cost of the ETF, but at present we cannot place a dollar value on many such parametric changes.

ETF DEVELOPMENT PROGRAMS

Figure 5 compares the construction and test schedules as developed by AVCO and General Electric*. The construction schedules are quite similar, with both calling for subsystem checkout and testing to start in the first quarter of the sixth year. The ETF is of such scale that it is not economical to build facilities for the checkout of major components prior to their installation; the contractors had to devise on-site procedures and facilities. Both developed schemes for saving time through the parallel testing of the bottoming plant and the MHD train, but used somewhat different approaches. General Electric provides an alternate test position for the second-stage combustor so that magnet testing and channel installation can proceed concurrently with the testing of the air heater and the combustor. The radiant boiler's separate firing feature is used to shake down the bottoming plant in parallel with the combustor tests. The combustor and bottoming plant are subsequently used to test the MHD generator system. AVCO separates the topping and bottoming cycles with an alternate water quenched bypass leg for the topping exhaust cycle, but does not make provision for the separate testing of the combustor. The radiant boiler is provided with oil guns capable of raising 30% of the design steam for testing of the bottoming plant.

There are considerable differences between the contractor testing schedules culminating in AVCO demonstrating the 2000-hour integrated

*The three versions of the G.E. schedule presented in their final report were not entirely consistent. We have been informed by G.E. that Fig. 1.1-1, "ETF Program Master Schedule - Tentative," should be followed in case of conflict.

endurance test two years prior to General Electric. The details in the plans are only sufficient to identify a few of the origins of these differences. G.E.'s plan anticipates problems and explicitly leaves periods for component debugging and modification whereas the AVCO plan does not. G.E. tests the combustor and bottoming plant sequentially, but it is not clear whether parallel testing could be used to accelerate the schedule. The AVCO plan calls for three phases: testing at 2500F air preheat, testing at 3000F preheat, and testing with the use of a coal gasifier to fire the air preheater. AVCO believes that the successful completion of the first phase provides sufficient justification for the decision to develop a commercial demonstration plant. If the use of 3000F preheat is required for this decision, then the completion dates for the two plans are in much better agreement. Combining these plans with the current DOE plans, which call for the start of the ETF project in mid-CY 83, results in a decision to build the commercial demonstration plant between 1990 and 1992.

CONCLUDING REMARKS

The ETF contractors differ substantially in their recommended plant design approach; they differ substantially in cost of expensive high-technology components, such as the magnet, and they recommend different plant implementation plans that would lead to as much as 2 years difference in demonstrating their stated ETF plant goals. During the coming year, the DOE will be funding additional system engineering studies related to both the ETF and potentially early commercial plants to resolve many of these issues. It is anticipated that a criteria document for the DOE ETF will not be written until mid-1979. Present DOE studies and component technology development efforts favor the separately-fired preheater plant with a low thermal loss combustor and slagging channel, but future studies and technology developments could alter the relative attractiveness of alternative approaches.

REFERENCES

1. Engineering Test Facility Conceptual Design, Final Report - AVCO Everett Research Laboratory, Inc. DOE FE-2614-2, June 1978.

2. MHD-ETF Program Final Report - General Electric Space Division. DOE FE-2613-6, March 1978.

3. MHD-ETF Conceptual Design, Final Report - Westinghouse Electric Corporation, Advanced Energy Systems Division. DOE FE-2363-2, April 1978.

4. Energy Conversion Alternatives Study (ECAS) Summary Report. NASA TM-7381, September 1977.

TABLE 1 - ETF CONTRACTOR TEAMS

Contractor	Contract Manager	Subcontractors
AVCO Everett Research Laboratory Everett, MA	Mr. Finn Hals	Chas. T. Main (Architect and Engineer) Comb. Eng. (Stm. Gen.) Magnet Eng. Assoc. (Magnet)
General Electric Company Space Division Philadelphia, PA	Mr. Lewin Terrey	Arthur G. McKee (Air Heater) Foster Wheeler (Stm. Gen) General Dynamics (Magnet) Maxwell Labs (Channel) Stearns-Roger (Architect and Engineer)
Westinghouse Electric Corporation Advanced Energy Systems Division Pittsburgh, PA	Mr. Frank Retallick	Morrison-Knudsen (Architect and Engineer) West. Res. Labs (MHD Comp.)

TABLE 2 - ETF REVIEW TEAMS

System Analysis
G. Seikel*, P. Staiger+; LeRC
J. Patton; ANL. J. Cutting; GAI

High Temperature Air Heater
J. Winter*, J. Burkhart+; LeRC
I. Pollack; ANL. R. Lawit; GAI

Combustion Technology
B. Phillips*, K. Smith+; LeRC
P. Chung, L. Carlson, J. Hanway; ANL
R. Kollrach, V. Underkoeffler; GAI

MHD System
J. Smith*, C. Pian+; LeRC
E. Doss; ANL
J. Cutting, R. Weinstein; GAI

Inverters
K. Prince; GAI. J. Mech; ANL

MHD Magnet
J. Burkhart*, LeRC
R. Niemann, S. Wang; ANL
P. Marston, A. Hatch; NML

Downstream Heat and Seed Recovery
T. Johnson*, W. Kann+, D. Bonkamp; ANL
P. Sheth; GAI. J. Winter; LeRC

Seed Reprocessing
A. Seth*, T. Johnson; ANL
M. Klett; GAI. J. Burkhart; LeRC

Balance of Plant, Layout, O&M, and Cost
R. Del Bueno*, R. Eakles+, S. Scherer; GAI
A. Rafer, P. Sheth, V. Pearson; ANL
R. Manly; LeRC

Materials
R. Singh*; ANL. A. Rowe+; LeRC

Instrumentation, Control, and Safety
K. Prince, W. Allison; GAI

Environmental Assessment and Siting
M. Novic; ANL. R. Stringer; GAI

*Chairman, +Secretary, NML - National Magnet Laboratory

TABLE 3 - SUMMARY OF CONTRACTOR RECOMMENDED ETF PLANTS

	AVCO	GENERAL ELECTRIC	WESTINGHOUSE
Total nominal fuel input, MW	250 290	260	340
MHD combustor air preheater, type	Separately-fired with 1100F recuperatively preheated comb.	Separately-fired with pressurized reheat	Directly heated with 1520F metal recuperator
Max. temp., °F	2500 3000	3000	2500
MHD combustor type	Single-stage with 80+% slag rejection	Two-stage (novel fluid bed first) 99+% ash rejection	Two-stage with 90% slag rejection
MHD generator/magnet/diffuser	High subsonic, with 6T max. field	High subsonic, with 6T max. field	High subsonic, with 6T max. field
Steam conditions (turbine if different) PSI/°F/°F	1265/950	3500(2400)/1000(950)/1000	1300/950
Contractor calculated plant performance, %	30 31.8	29.2 (30.1)*	34.9
Estimated cost mid-1977 10^6\$, no escalation or interest	235	282	304
Special aspects of plant	Provision for pretesting MHD train with scrubber, uses recovery boiler technology, ultimately to use gasifier to provide preheater fuel.	Combustor electrical isolation between stages. Hot cyclone seed collection. Motor driven air compressor. Provision for combustor check-out and steam only operation.	Final configuration evolves from initial O_2 enriched no high temperature preheat MHD train test facility.
Emphasis of study	Understanding of basic configuration and aspects of off design.	Evaluation of alternate component designs. Seed reprocessing not in contract.	Systems analysis of alternative plant configurations and sizes.

*With either dry ash separation for fluid bed or alternate cyclone combustor.

TABLE 4 - NONDIMENSIONAL ETF PLANT PARAMETERS

QUANTITY IN PERCENT	PLANT AVCO 3000F PREHEAT	G.E. PREFERRED	WESTINGHOUSE RECOMMENDED
Ratio preheater fuel (HHV) to total fuel (HHV)	35	34	0
Ratio preheater recuperation/ regeneration to total input	23	13	100
Ratio power input MHD generator to MHD combustor	94	85	95
Ratio MHD power to MHD generator input	16	16	18
Ratio net MHD power to MHD generator input	12	10	12
Efficiency MHD compressor (isentropic)	84	80	83
Ratio stack power to total fuel (HHV) input	10	13	18
Ratio all other power losses to total fuel (HHV) input	4.9	13	2
Efficiency steam turbine(s)			
combined	33	37	35
turbine/generator	33	37	35
turbine/compressor	32	-	35
Efficiency inverter	98	98	96
Ratio auxiliary power to gross power	10	13	7.2
Ratio seed reprocessing power to total fuel (HHV) input	.2	NA	2.2
Efficiencies			
Thermodynamic cycle	35	34	38
Plant without seed reprocessing	32	29	36
Plant including seed reprocessing	32	-	35

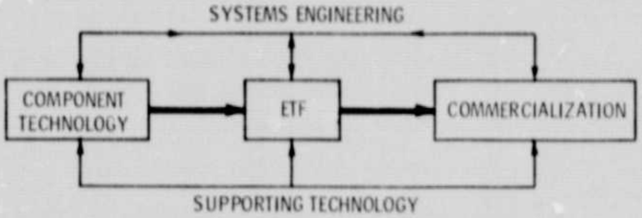

Figure 1. - ETF provides the major DOE focus in implementing the commercialization of MHD.

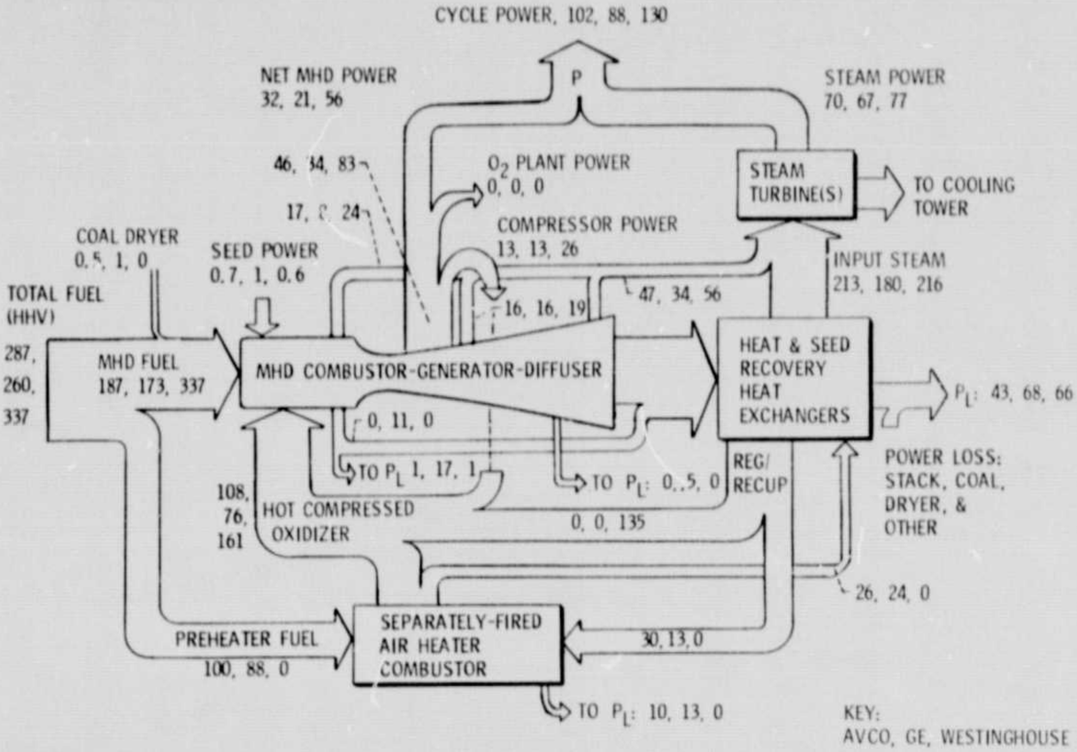

Figure 2. - Simplified MHD/steam cycle power diagram.

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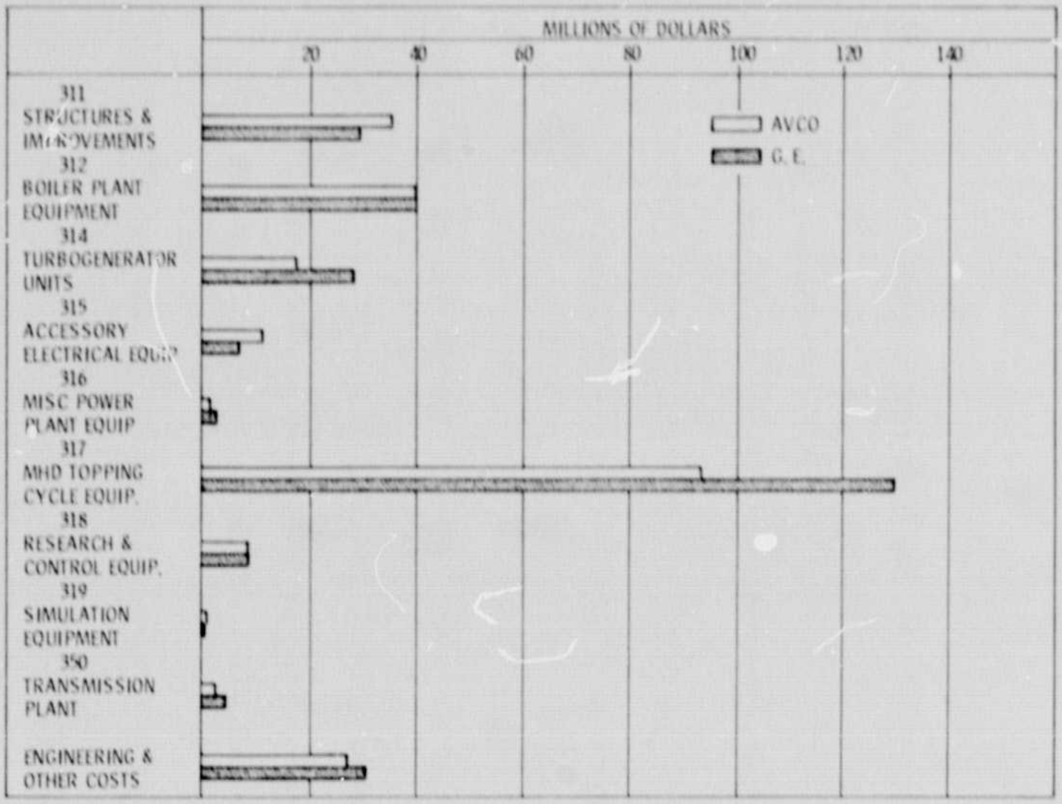


Figure 3. - Comparison of AVCO & G. E. ETF costs by major account codes.

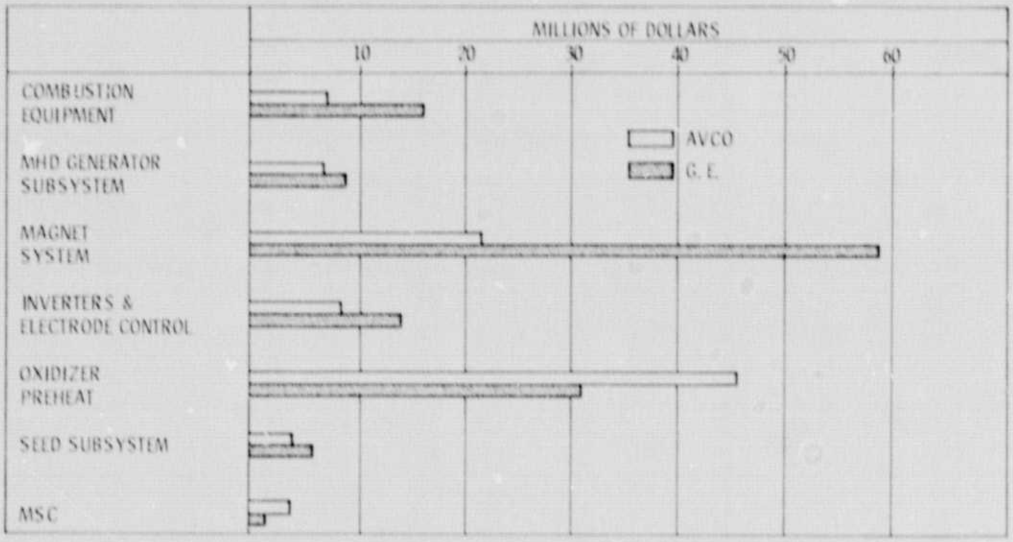
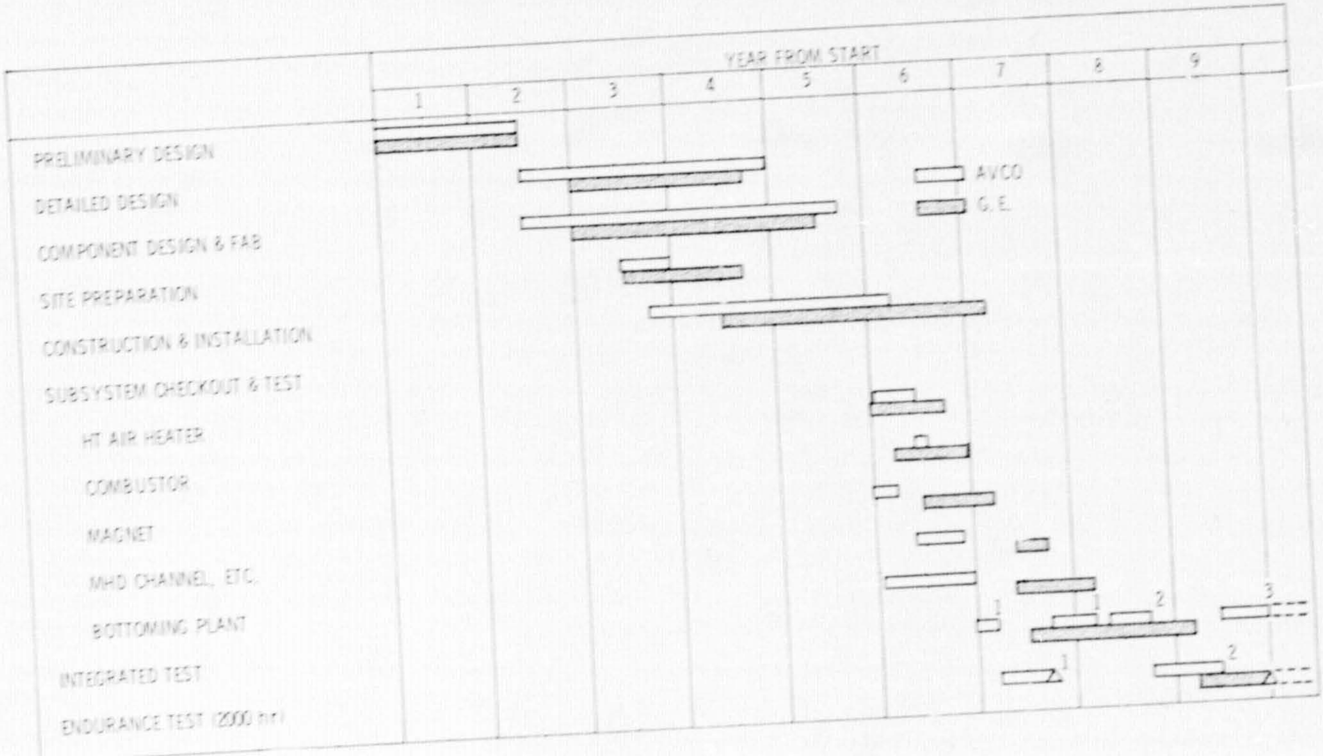


Figure 4. - Comparison of AVCO & G. E. ETF costs for MHD topping cycle.



NOTES:

△ 2000 hr DEMONSTRATION MILESTONE

1. 2500° F AIR PREHEAT
2. 3000° F AIR PREHEAT
3. COAL GASIFIER

Figure 5. - Comparison of AVCO & G.E. ETF project schedules.